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An experimental investigation of the performance of metallic and sandwich ship bulkheads under combined thermo-mechanical loading

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INTRODUCTION

Despite the well know advantages of composite materials that have consolidated their implementation in a variety of industrial applications, very few non-military applications exist in the marine industry. In fact, the majority of marine structures is almost exclusively designed and manufactured using metallic materials despite the fact that these lead to heavy designs, and they are susceptible to corrosion and fatigue. The reason why composites have not been implemented in commercial shipping is because until 2002, when the so-called regulation 17 was introduced, SOLAS regulations did not allow the use of combustible materials onboard ships [1]. Nevertheless this rule has proven hard to implement as the evaluation and acceptance of designs encompassing composite materials has proven cumbersome. Moreover, the existing set of regulations were introduced at a time when metallic materials were the sole option and as such they do not explicitly address issues related to the performance of composite materials but rather try to enforce the same operational criteria that exist for metallic structures to their composite counterparts. The scope of this work is to compare the performance of three different structural bulkhead designs, located at the superstructure of a passenger ship, under combined thermal and mechanical loading following the prescribed FTP code standards [2]

EXPERIMENTAL TESTING

A. SPECIMEN DESCRIPTION

A RoPax ferry operating between Denmark and Germany has been selected as the study case for the design of the bulkheads. The tested specimens were made out of steel, aluminum and sandwich comprising of glass/epoxy skins with DIAB P100 core. The aluminum and the sandwich bulkheads were designed in accordance with DNV's rules. In detail the design loads were calculated according to the DNV Rules for Classification of Ships [3] while the scantling calculations were performed according to DNV's Rules for Classification of High Speed, Light Craft and Naval Surface Craft [4,5]. The steel bulkhead was constructed based on the available drawings of the ship's steel structure. All specimens were 3.1m high by 2.93 m wide and were tested in the facilities of the Danish Institute of Fire and Security technology. The dimensions of each specimen are listed in Table 1.The material used were common grade structural steel, 6082 temper 5 Aluminum alloy and 450g/m^2 biaxial stitched glass fabric and Prime 20LV epoxy resin. The layup is presented in Table 2. After the specimens were manufactured insulation was applied from the stiffener side provided by Morgan Ceramics.

Table 1: Specimen dimensions

	Specimen thickness	Stiffener details
Steel	t_{plate} = 6.5 mm	4 x Bulbflats 100x7, 700mm spacing
Aluminum	t_{plate} = 6.0 mm	4 x Angle bars 80x40x6, 700mm spacing
Composite	$t_{sandwich}$ = 43.0 mm	No stiffeners

Table 2: Composite bulkhead layup

2x 450g/m^2, Stitched fabric 0^o/90^o
2x 450g/m^2, Stitched fabric +/-45^o
DIAB P100 Core 40mm
2x 450g/m^2, Stitched fabric +/-45^o
2x 450g/m^2, Stitched fabric 0^o/90^o

B. TESTING PARAMETERS AND INSTRUMENTATION

The specimens were tested following the FTP code which prescribes that a constant load of 7.0 kN/m width is applied on the top of the specimen and that the furnace temperature follows the one prescribed in ISO834 [6]. All specimens were placed with the insulated side facing towards the furnace. Thermocouples were positioned in different positions between the insulation and the exposed side as well as in the unexposed side. In the composite bulkheads additional thermocouples were positioned in different positions inside the core to capture the temperature gradient across the thickness of the sandwich structure. The displacement of the specimens was monitored both using analogue equipment and also using the digital image correlation technique. At this point it must be emphasized that the FTP code is a certification standard therefore a bulkhead can be considered as A-60 or FRD-60 if it is made out of combustible materials if it satisfies a predefined set of performance criteria within a specific limit. As such, there are no additional requirements after the predefined time limit which in this case was 60 minutes. However it was considered crucial to investigate how the structures behave after the 1 hour time frame as there have been incidents where an uncontrolled fire was raging for several hours before the evacuation of the passengers and therefore the implicit robustness of the structure is crucial for the safety of the passengers and the crew.

C. RESULTS

Results indicated that all three specimens successfully passed the

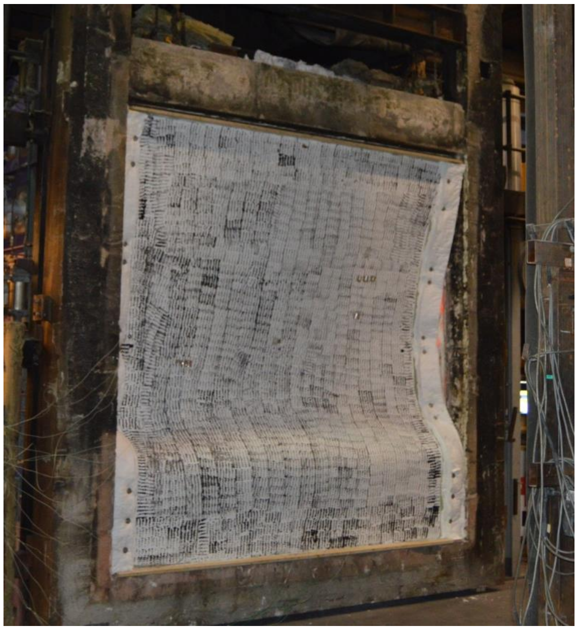
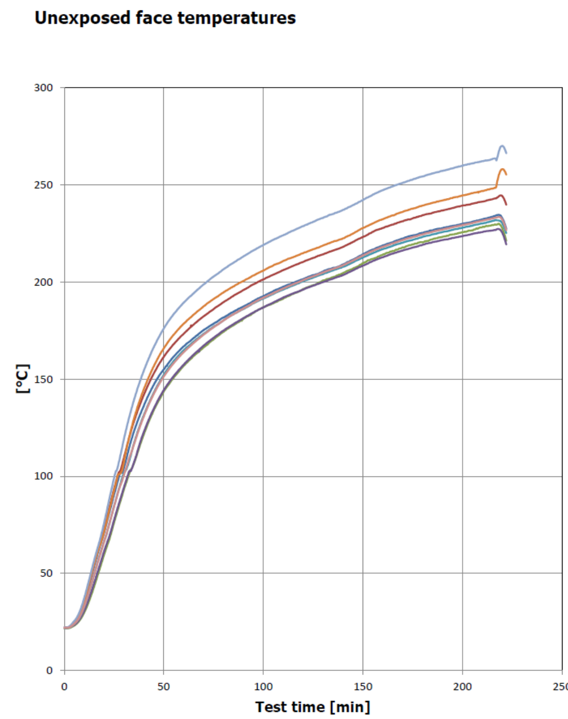


Fig. 1: Failure of the composite bulkheads after 82 minutes

FTP code requirements. However the behavior of the specimens differed. For the metallic cases no catastrophic damage occurred and their structural integrity was not influenced from the loading. On the contrary catastrophic failure occurred for the composite one (Figure 2). The failure was caused due to the softening of the exposed skin after reaching a temperature of about 300°C on the surface covered by the insulation by then the temperature 5mm from the core had reached about 140°C indicating that the skin laminate has suffered significant material degradation which led to asymmetric loading and eventually collapse of the bulkhead. Nevertheless, it must be pointed out that there is a big difference in the reserve factor of the specimens as the steel one that is grossly overdesigned since it is common practice to try to keep a uniform design in the bulkheads based on the available raw materials of the shipyard and also so in order to simplify manufacturing. Another interesting result is that in the case of the composite bulkhead the temperature profile in the unexposed side was significantly lower compared to the metallic specimens meaning that it is actually more effective in controlling the fire in the space were it first manifested. Additionally the fire-fighting strategy for a composite case is more straightforward as boundary cooling, which is necessary in metallic structures, need not take place.

D. CONCLUSIONS

Three alternative configurations, namely steel, aluminum and sandwich have been tested following the FTP code. All specimens were able to satisfy the A-60 and FRD-60 requirements. Interpreting the results from an implicit robustness point of view the metallic ones performed better as they were able to sustain the applied load without failing, but it must be noted that the FRP bulkhead was superior in containing the fire loading. Additionally, the loss of a structural member will not necessarily mean that the load bearing capacity of the structure is compromised as the load will be redistributed to adjacent structural components which will not be influenced thanks to the composite structures low heat transferring properties. Therefore controlling the fire before it can spread to other



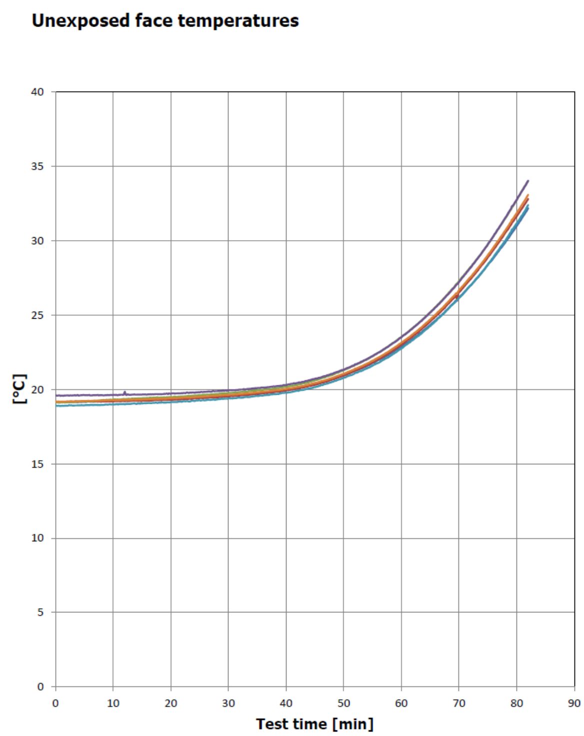


Fig. 1: Temperature versus time for the aluminum specimen (up)and FRP (down)

spaces is more vital for the safety of the passengers and the crew and in that perspective the sandwich structure performed more satisfactory compared to the metallic ones.

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APPENDIX: SUBMITTING PDF FILES

Authors must submit the (PDF) version of their abstract via Email : info@icss11.org (max 18MB)